



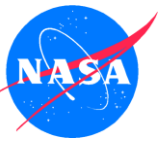
***ESIP Summer Meeting, July 2010, Knoxville, TN***

# **Using NASA Satellite and Model Analysis for Renewable Energy and Energy Efficiency Applications**

***Paul Stackhouse (NASA LaRC)***

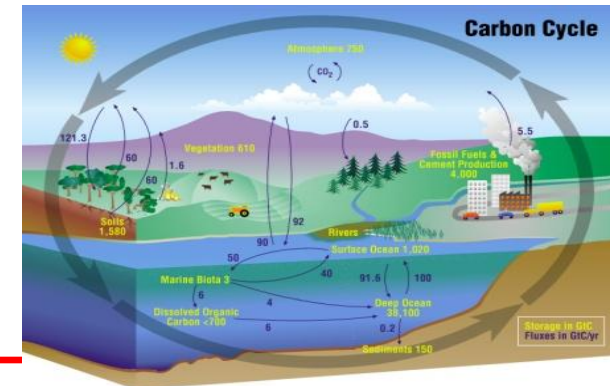
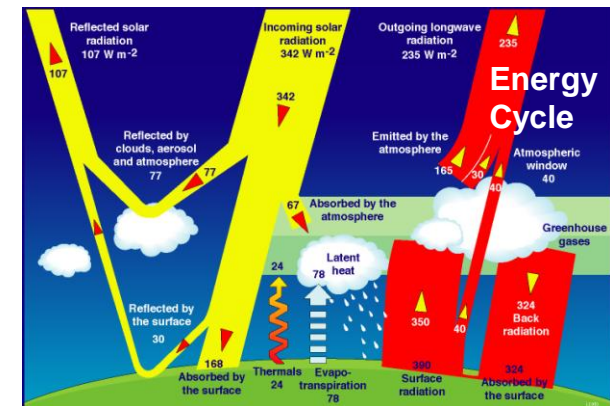
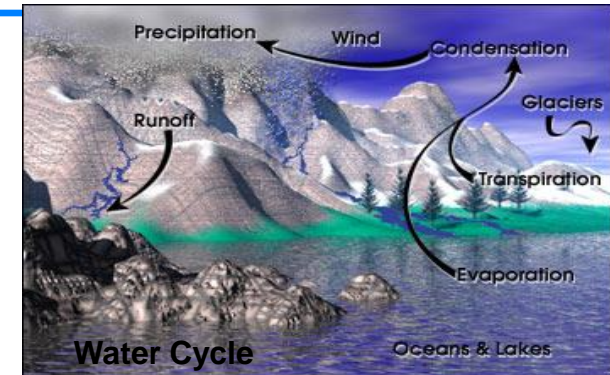
***Charles H. Whitlock, James. M. Hoell, David Westberg and  
Taiping Zhang (SSAI ),***

***and grateful acknowledgement to NASA Partners at GISS,  
GMAO, LaRC ASDC, Partners at DOE NREL, NRCan  
RETScreen, State University of New York - Albany and  
numerous small companies***



# Researching Science Questions

- *How is the global Earth system changing?*
- *What are the primary forcings of the Earth system?*
- *How does the Earth system respond to natural and human-induced changes?*
- *What are the consequences of changes in the Earth system for human civilization?*
- *How well can we predict future changes to the Earth system?*

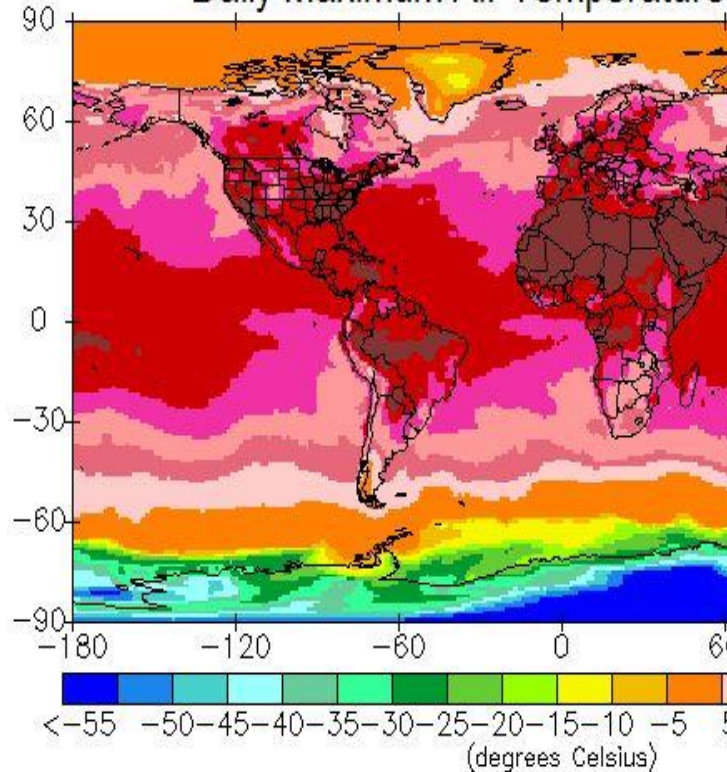




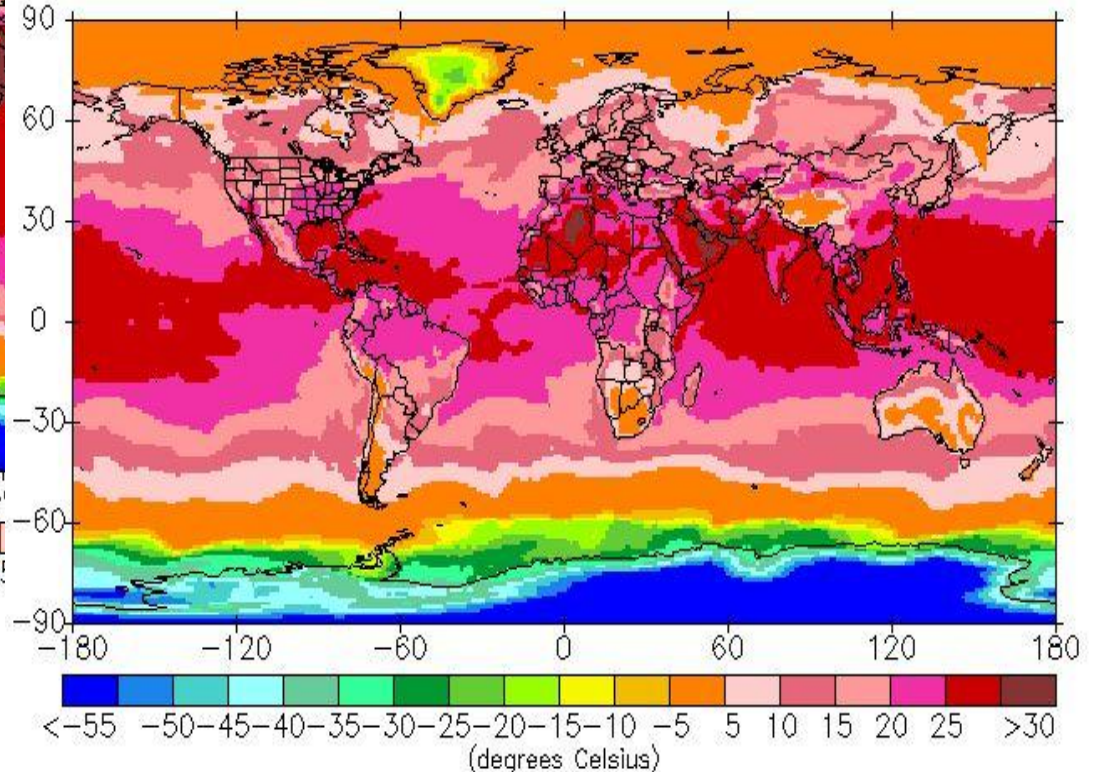
# Relevant NASA Science Data Sets

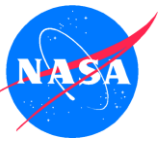
## *Meteorological Information from GMAO*

Daily Maximum Air Temperature For July 4, 2006



Daily Minimum Air Temperature For July 4, 2006





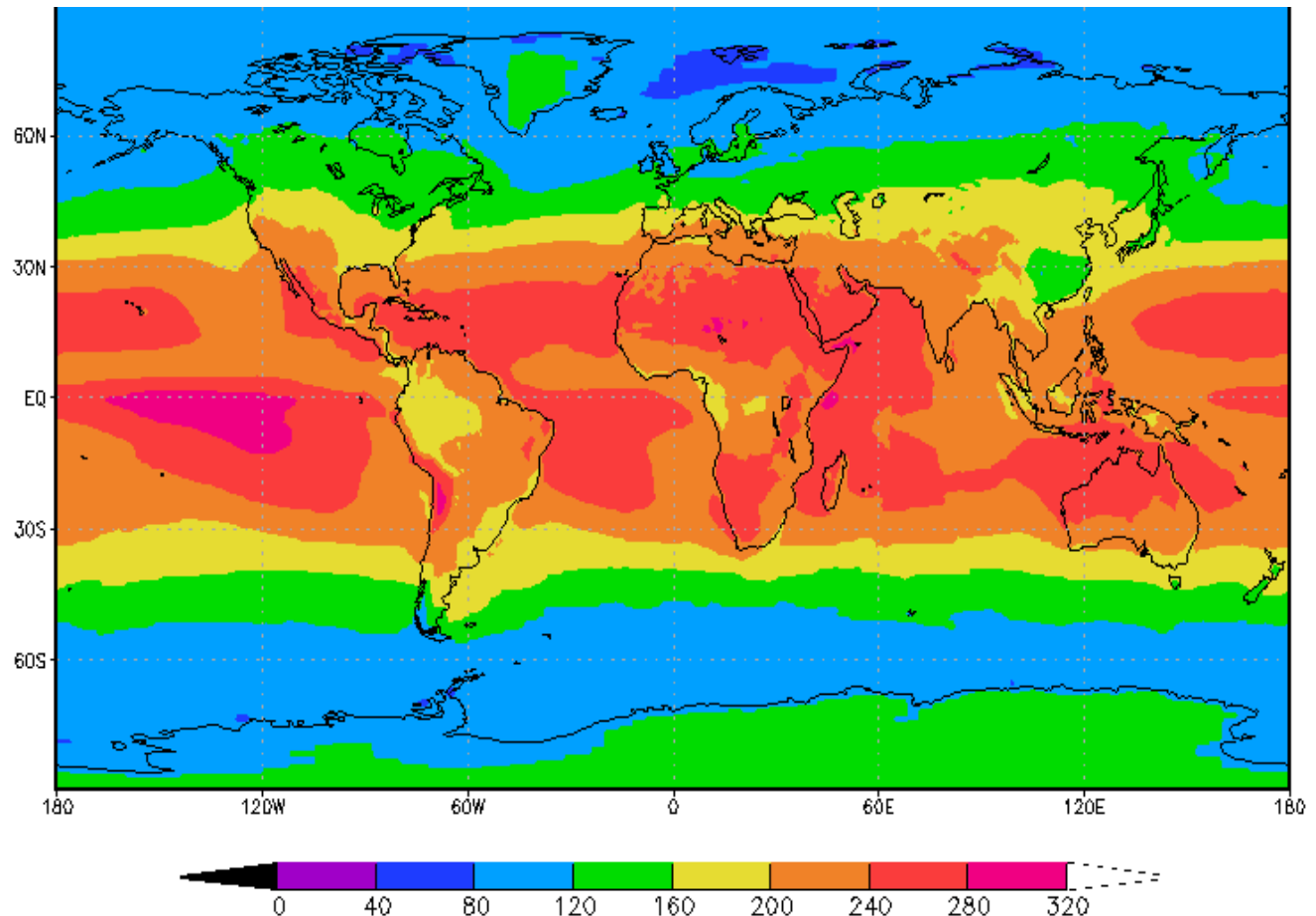
# Relevant NASA Science Data Sets

*GEWEX Surface Radiation Budget: 24+ years of cloud  
(from ISCCP), SW and LW fluxes at TOA and Surface*

**GEWEX SRB  
SW v3.0  
(ISCCP, GMAO)**

*24 Year Annual  
Average Surface  
Solar Fluxes  
( $W m^{-2}$ )*

*(Jan 1984 –  
Dec 2007)*



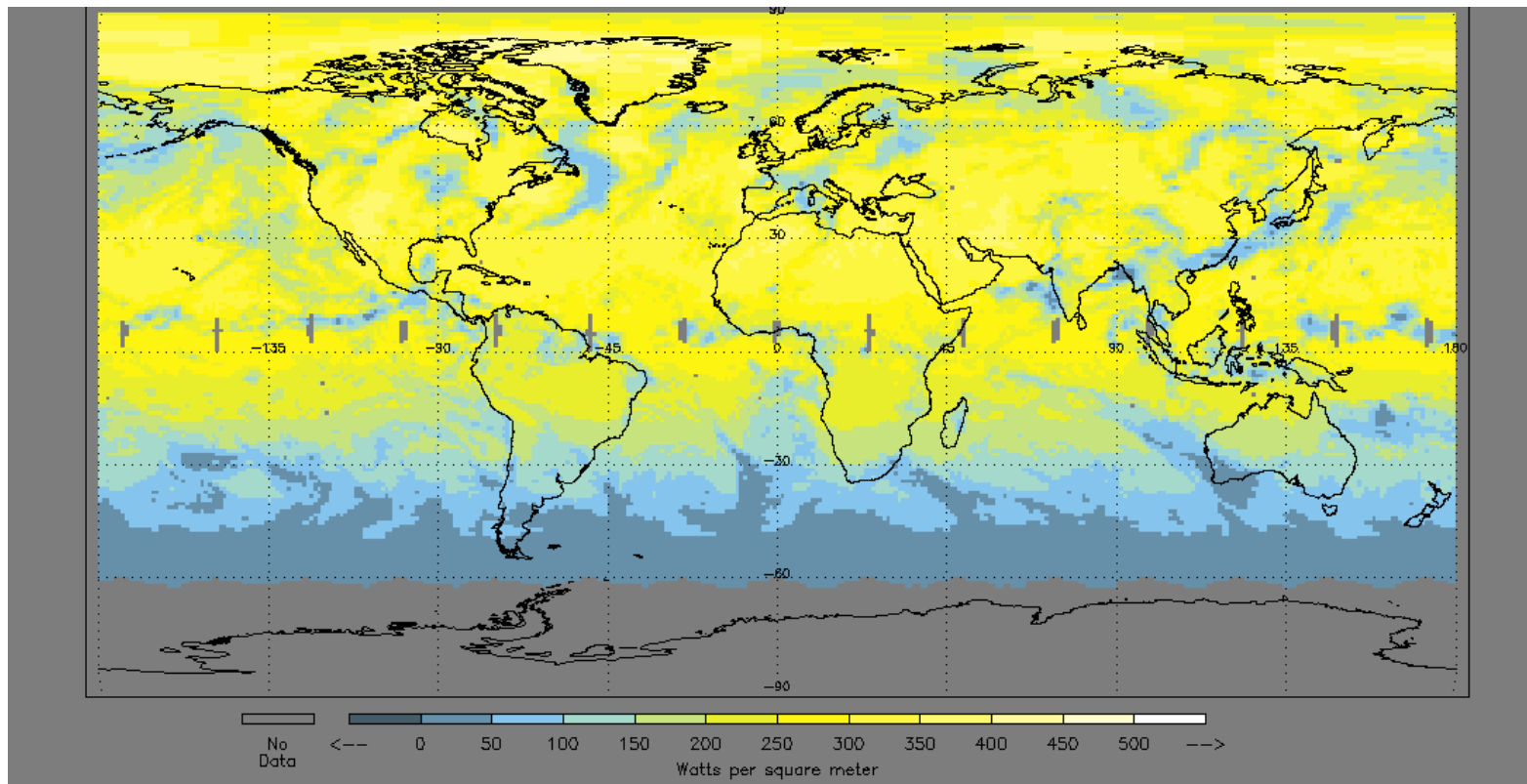




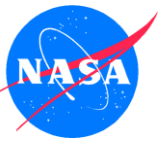
# Relevant NASA Science Data Sets

*FLASHFlux: Global TOA and Surface Fluxes within  
1 week of observation from Terra and Aqua*

**FLASHFlux (CERES/MODIS, GMAO)**

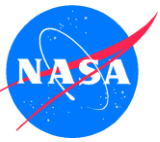


***Daily Average Solar Irradiance for June 15, 2010 ( $\text{Wm}^{-2}$ )***



# NASA Applied Sciences Program

- ***Applied Sciences Goal:*** The Applied Sciences program extends NASA Earth Science research and observations for practical use in environmentally-related decision and policy making.
- ***Serves society through:***
  - Demonstrating, through partnerships with public organizations, improvements to their ability to manage and plan natural resources and to make better environmental predictions, decisions, and policy.
- ***Serves the Earth science community by:***
  - Demonstrating and communicating the utility and potential of Earth science for societal benefit to a broad audience
  - Complementing R&A programs through applied research in strategic areas
  - Providing the applications “viewpoint” to the research community (e.g., working with GEO and CEOS)
  - Forging partnerships with “nontraditional” organizations (e.g., NREL, USDA, Battelle, NRCAN, ESA, DLR, Universities, Private Sector)



# Societal Benefit Areas

**Applied Sciences aligns with GEO Societal Benefit Areas, with a focus on those areas where:**

- NASA has capability and expertise
- NASA can have greatest impact
- Societal need is greatest



Public Health



Disaster Management



Weather



Water Resources



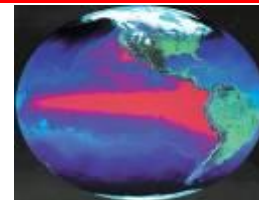
Agriculture



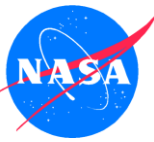
Ecosystems



Air Quality



Climate



# Energy Projects in NASA Applied Science

## POWER = Prediction of Worldwide Energy Resource

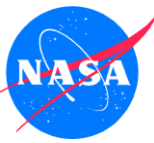
Objective: Improve the Nation's public and private capability for integrating environmental data from NASA's satellite-based analysis and modeling research into sound management of energy production and energy efficiency systems.

### Goals:

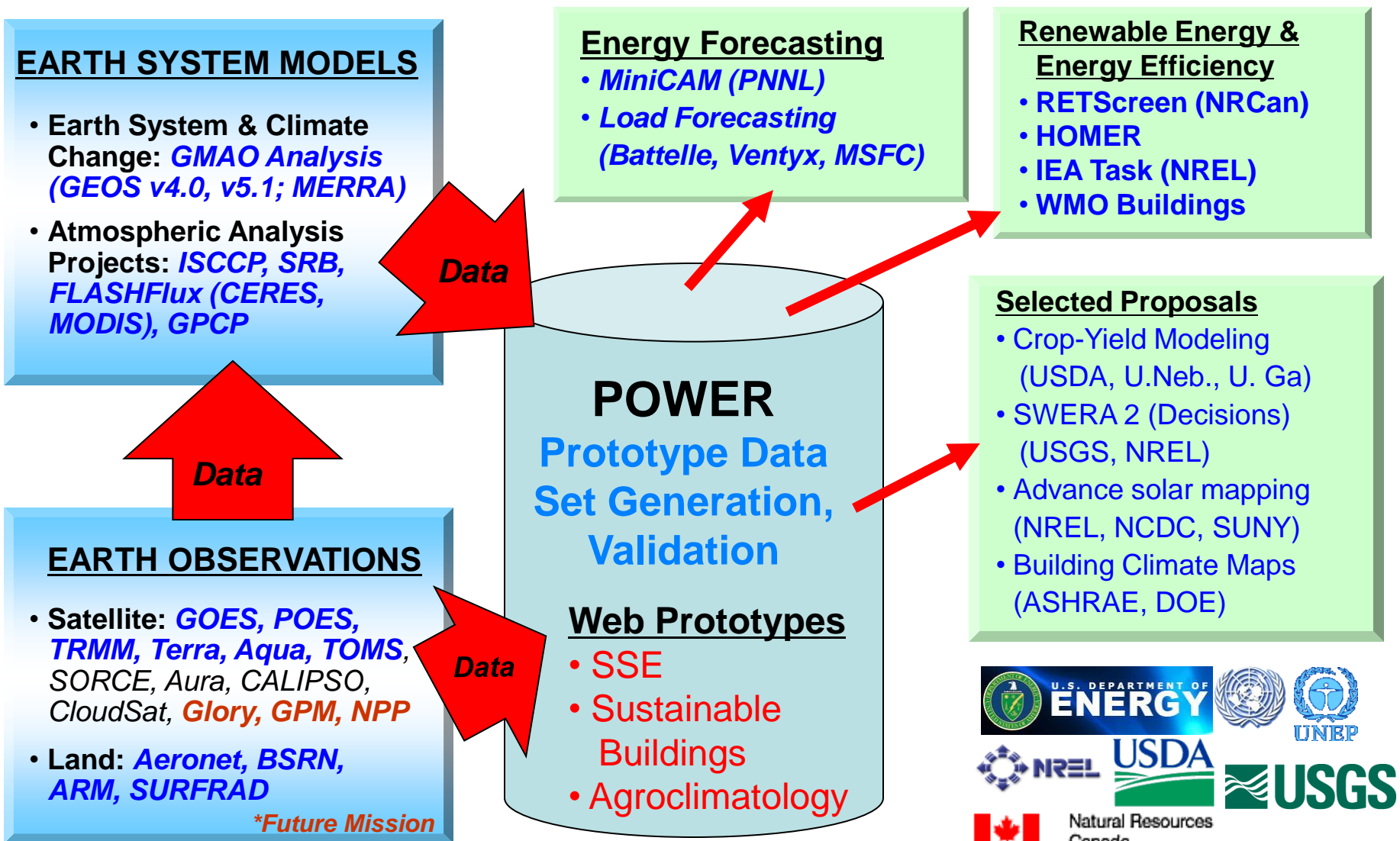
1. Establish partnerships to facilitate the integration and adaptation of NASA satellite analysis and modeling data into electric power industry Decision Support System's (DSS) and databases.
2. Target such datasets for Electric Power, Renewable Energy, Energy-Efficient Building Design and Biomass Crop Development Industries
3. Transition operational capabilities to government and/or private sector entities.

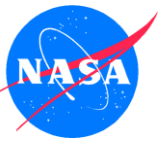




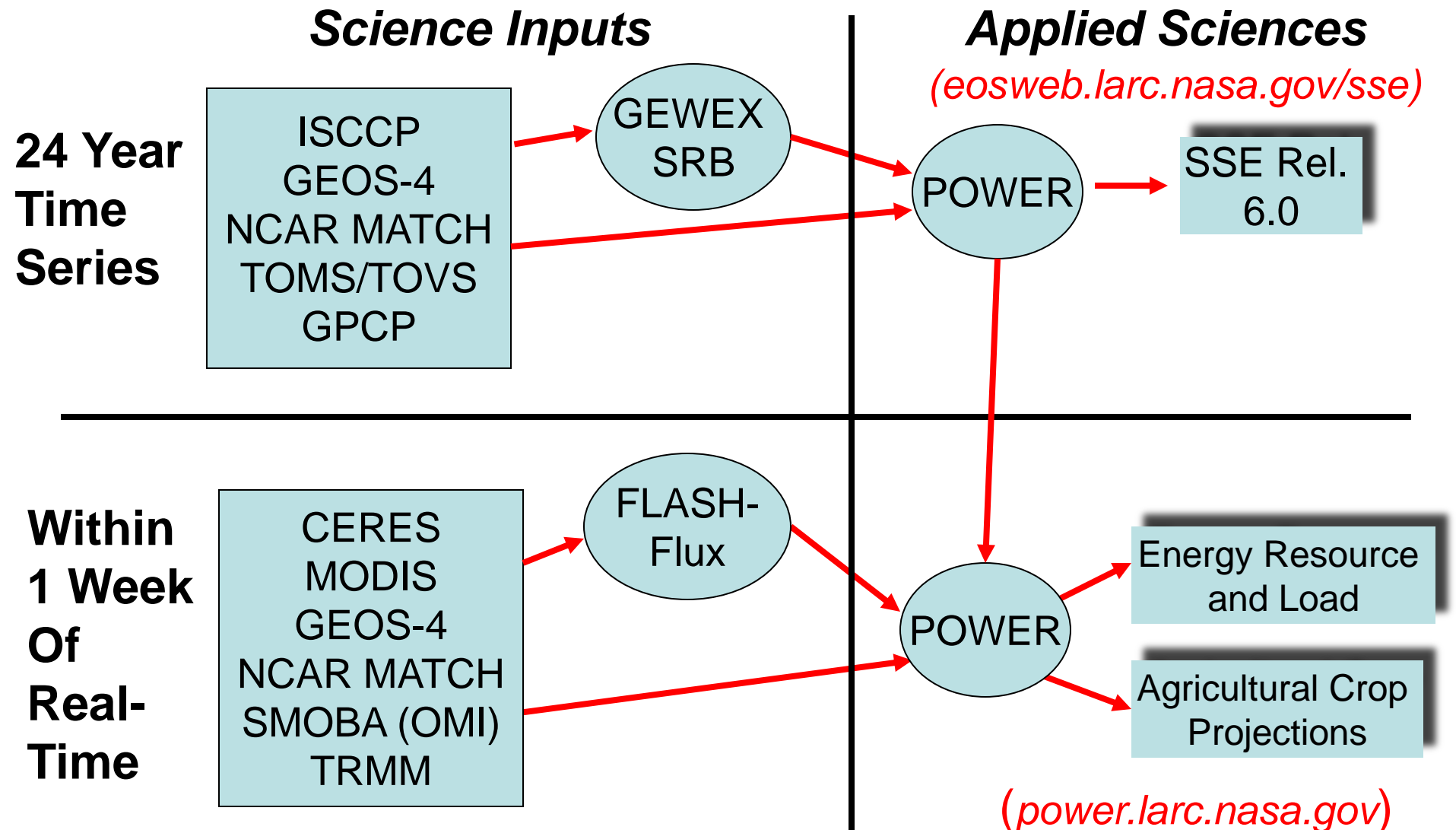


# POWER: Hub for Energy Applications





# Current Data Product Data Flow





# NASA SSE Release 6.0


- 23 Years
- New parameters
- Updated Solar algorithm
- Improved validation
- Increased accessibility including regions/time series
- Direct connection to 3 renewable energy DSS tools

<http://eosweb.larc.nasa.gov/sse>


Surface meteorology and Solar Energy

<http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?p.w.stack> Google

Getting Started Latest Headlines

 **ATMOSPHERIC SCIENCE DATA CENTER**




**Surface meteorology and Solar Energy**  
*A renewable energy resource web site (release 6.0)*  
sponsored by NASA's [Earth Science Enterprise](#) Program











**HIGHLIGHTS**

- over 200 satellite-derived meteorology and solar energy parameters
- monthly averaged from 22 years of data
- data tables for a particular location
- color plots on both global and regional scales
- global solar energy data for 1195 ground sites



**Data Retrieval:**



-  [Meteorology and Solar Energy](#)
-  [Ground Site](#)
-  [Renewable Software Application Inputs](#)

**Supporting Documentation:**

-  [Horizontal Grid for Input and Output](#)
-  [Accuracy](#)
-  [Methodology](#)
-  [Parameters \(Units & Definition\)](#)
-  [Frequently Asked Questions \(FAQ\)](#)
-  [Related Web Sites](#)
-  [Join SSE mailing list / Submit Questions](#)
-  [Partners and Performance](#)

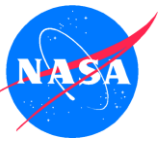
**HOMER RETScreen SolarSizer**

**Responsible Officials** Data: [Paul W. Stackhouse, Jr., Ph.D.](#)  
[Charles H. Whitlock, Ph.D.](#)  
Archive: John M. Kusterer  
Site Administration/Help: NASA Langley [ASDC](#) User Services ([larc@eos.nasa.gov](mailto:larc@eos.nasa.gov))  
([Privacy Policy](#) and [Important Notices](#))  
Document generated on Thu May 1 16:11:40 EDT 2008

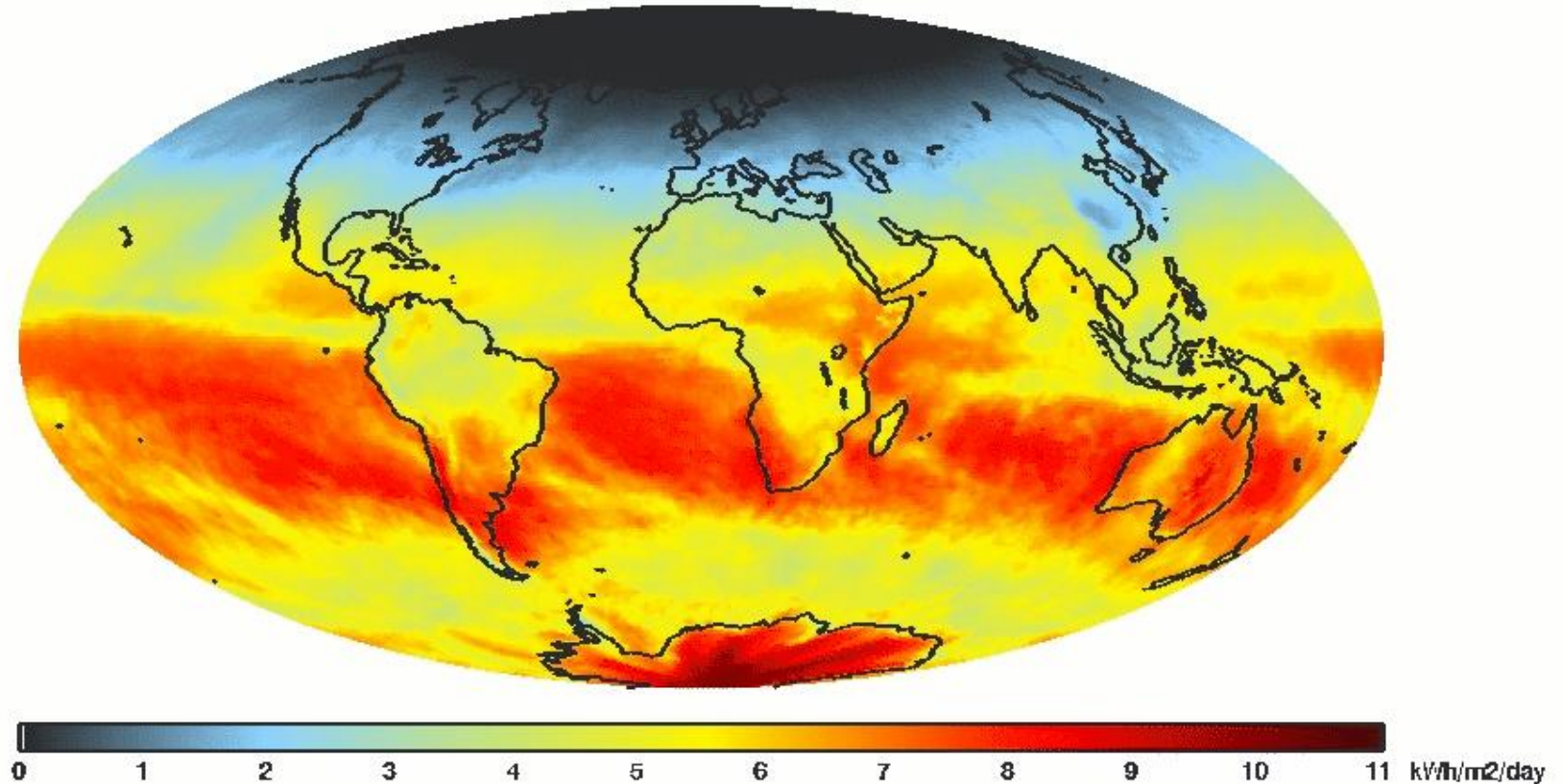
Done



# Relevant NASA Science Data Sets

## *Global Monthly Irradiance for 2000 (from GEWEX SRB)*

Average Daily Solar Radiation for 2000 Jan





Parameters for Sizing Battery or other Energy-storage Systems:

Equivalent Number Of NO-SUN Or BLACK Days (days)

Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 day	0.96	0.95	0.95	0.93	0.91	0.92	0.95	0.89	0.92	0.96	0.94	0.96
3 day	2.61	2.38	2.46	2.66	2.47	1.89	2.16	2.39	2.07	2.37	2.46	2.44
7 day	5.08	4.51	4.53	3.95	4.48	3.33	3.53	3.58	3.61	4.43	3.58	4.11
14 day	7.15	6.14	4.08	5.31	6.77	4.35	3.98	4.95	4.57	5.39	4.74	7.12
21 day	6.19	8.35	5.00	5.24	7.35	4.93	5.12	6.02	3.70	7.40	5.82	8.44
Month	4.60	7.63	3.60	5.26	9.01	3.67	4.27	5.24	4.17	6.81	6.49	6.65

[Parameter Definition](#)

Parameters for Sizing Meteorology (Temperature):

Monthly Averaged Cooling Degree Days Above 18° C

Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Sum
22-year Average	0	0	4	22	86	189	257	224	130	34	5	1	952

[Parameter Definition](#)

Meteorology (Wind):

Monthly Averaged Wind Speed At 50 m Above The Surface Of The Earth (m/s)

Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	6.60	6.71	6.67	6.04	5.13	4.88	4.34	4.17	4.80	5.38	6.27	6.65	5.63

Minimum And Maximum Difference From Monthly Averaged Wind Speed At 50 m (%)

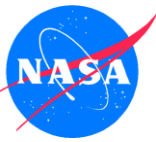
Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Minimum	-13	-11	-14	-10	-13	-11	-10	-16	-8	-11	-8	-11	-11
Maximum	13	8	9	15	16	9	11	10	11	9	10	7	11

It is recommended that users of these wind data review the SSE [Methodology](#). The user may wish to correct for biases as well as local effects within the selected grid region.

All height measurements are from the soil, water, or ice/snow surface instead of "effective" surface, which is usually taken to be near the tops of vegetated canopies.

[Parameter Definition](#)

[Units Conversion Chart](#)



# Parameter Validation: Key to Usage

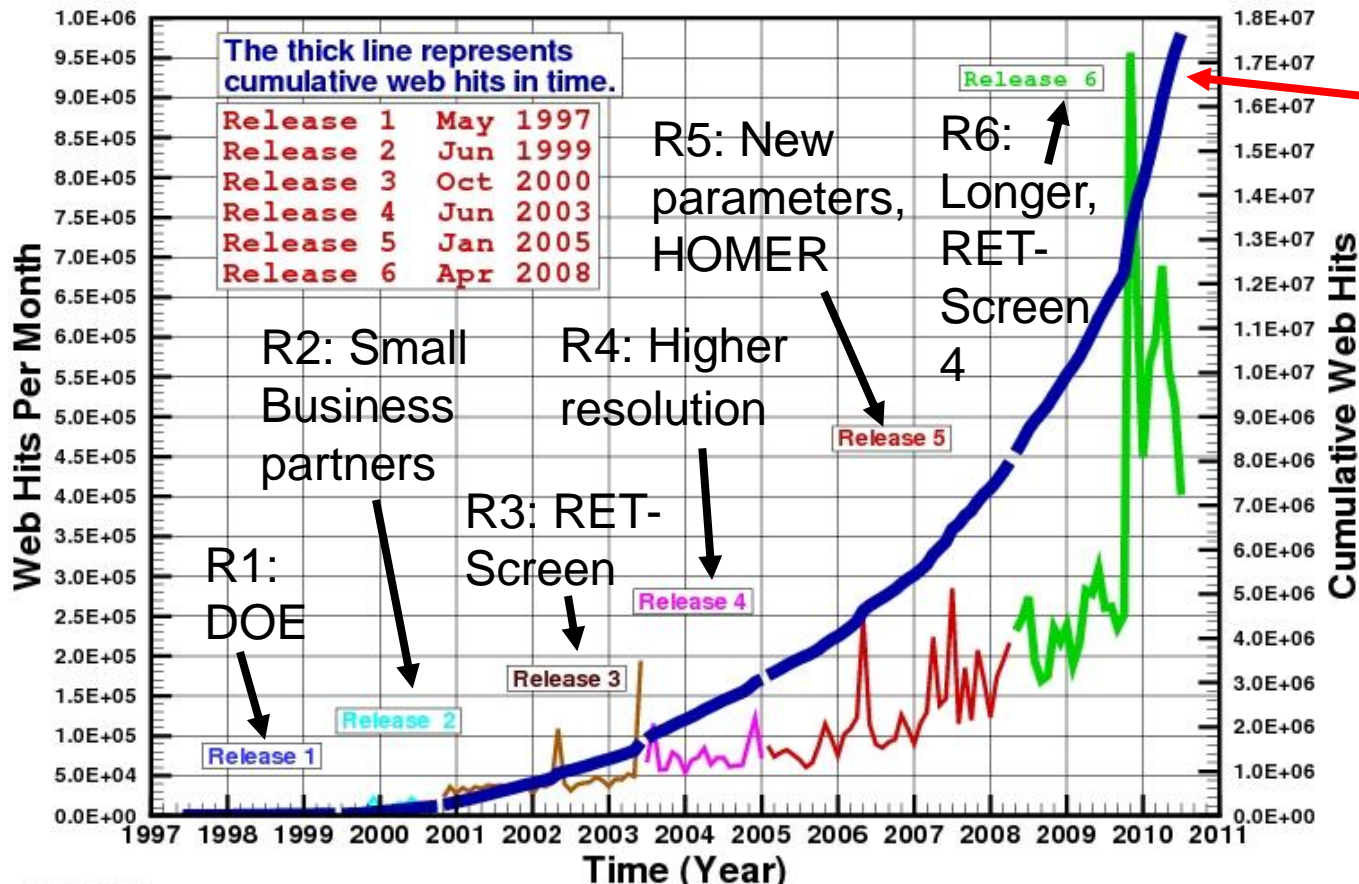
*Power validation significant, included in extensive methodology document*

per	Table I-1: Regression analysis of SSE versus BSRN monthly averaged values for the time					
	Table I-2: Linear least squares regression analysis of SSE versus NCDC monthly averaged values for the time period 1983 through 2006					
Hoi	Parameter	Slope	Intercept	R <sup>2</sup>	RMSE	Bias
	Tmax (°C)	0.00	-1.58	0.05	3.12	-1.83
Hoi	Tmi	Table I-3: Estimated uncertainty for monthly averaged wind speed for the time period July 1983 through June 1993				
	Tav					
Dir	Tde	Parameter	Method		Bias	RMSE
	RH	Wind Speed at 10 meters for terrain similar to airports (m/s)	RETScreen Weather Database (documented 10-m height airport sites)		-0.2	1.3
	Hea (deg		RETScreen Weather Database (unknown-height airport sites)		-0.0	1.3
Cooling Degree Days (degree days)		0.86	2.36	0.92	28.90	-5.65
Atmospheric Pressure (hPa)		0.89	102.16	0.74	27.33	-10.20



# POWER Sustains Growth of SSE Prototype and Web Interface

## Surface meteorology and Solar Energy (SSE) Web Interface Usage

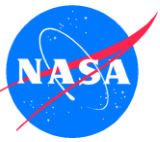


> 17.5 million total hits and ~4 million data requests since 1997 inception

Now >75,000+ users, ~2.5X increase since 2007, >1900 new users per month in 2010

## Monthly Averaged Usage Statistics

Per Month	Rel. 1	Rel. 2	Rel. 3	Rel. 4	Rel. 5	Rel. 6	Growth
Web Site Hits	1,278	12,533	35,000	74,500	121,180	366,200	285:1
Data Downloads	59	873	3,000	12,530	20,055	98,800	1675:1



# Connecting to Decision Tools

## *Direct Linkage to Building/Renewable Energy Decision Support*



### Renewable Software Application Inputs

- **HOMER [data access](#)**

The Hybrid Optimization Model for Electric Renewables ( [HOMER](#) ) is used for designing standalone electric power systems that employ some combination of wind turbines, photovoltaic panels, or diesel generators to produce electricity.

- **RETScreen<sup>®</sup> International [data access](#)**



A collaboration with the CANMET Energy Technology Centre - Varennes (CETC-Varennes) has produced satellite data output useful to users of the RETScreen<sup>®</sup> International Clean Energy Project Analysis Software. [RETScreen<sup>®</sup> International](#) can be obtained free of charge from CETC-Varennes.

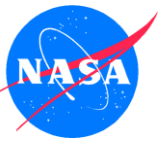




# RETScreen

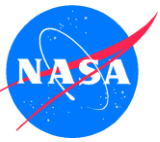
www.retscreen.net

- Clean Energy Project Analysis Tool
- Aimed for both feasibility and detailed scenario analysis
- Built on Excel
- Partners since 2000



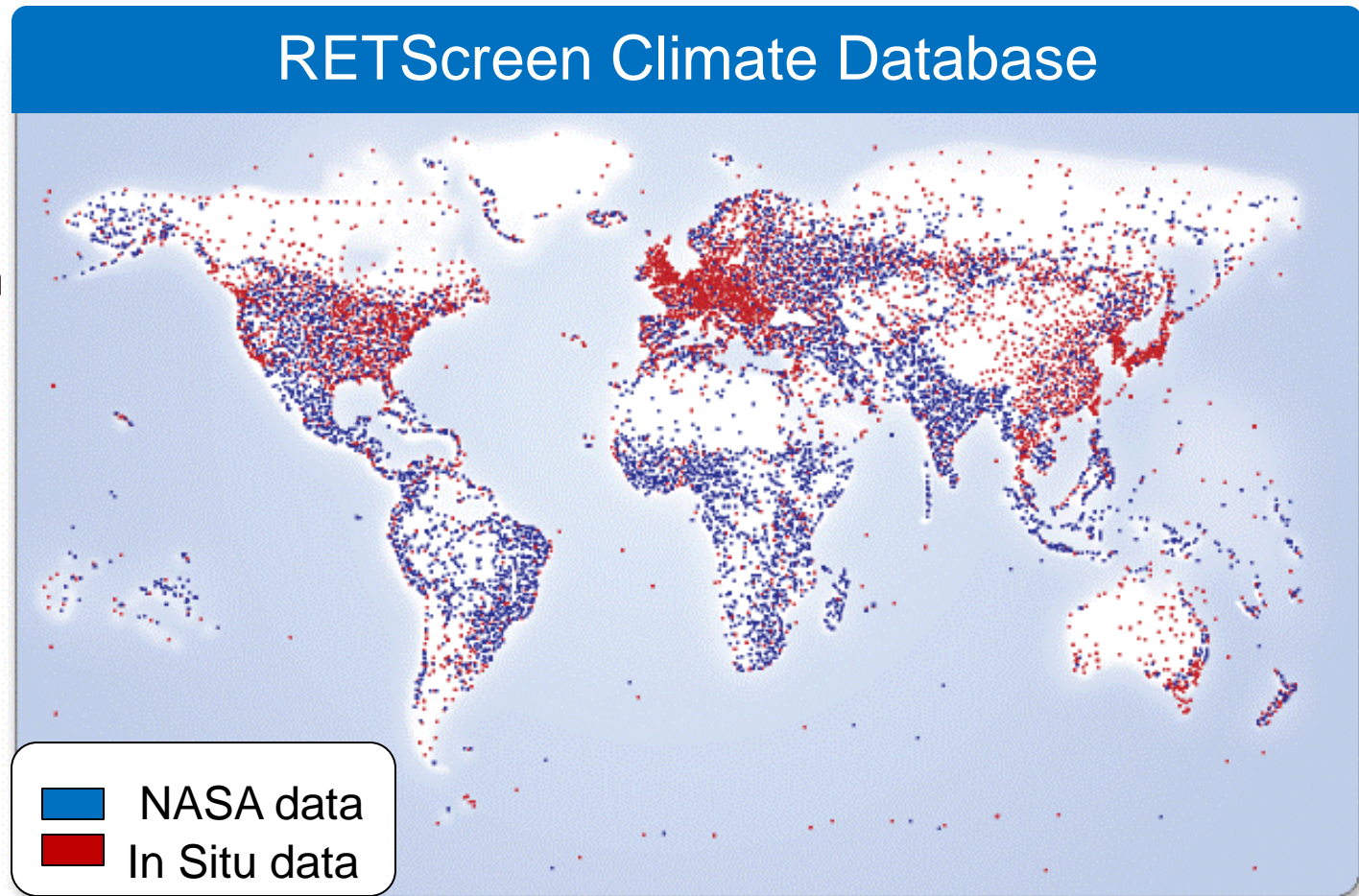
# Example RETScreen Clean-Energy Analysis Projects

- **Wind Energy:** *wind turbines, integration*
- **Small Hydro-Electric Power**
- **Photovoltaic Technology & Applications:** *household PV, water pumping, grid-tied building integrated PV*
- **Combined Heat and Power:** *Applications (residential, commercial, building clusters, district energy systems etc.), Fuels (biogas, wood residue, etc.), Equipment (heating and cooling, power generation)*
- **Biomass Heating:** *wood chip, heating*
- **Solar Air Heating:** *solar thermal walls*
- **Solar Water Heating:** *residential and commercial*
- **Passive Solar Heating:** *illumination angles; windows*
- **Ground Source Heat Pump Tech & Applications**



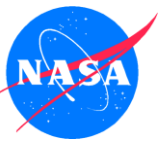
# RETScreen's Reliance on POWER Data

- Built-in cities of world
- Direct query of SSE data through web
- 255,000+ users
- 222 countries
- 1000 new users every week
- Release 4: 36 languages



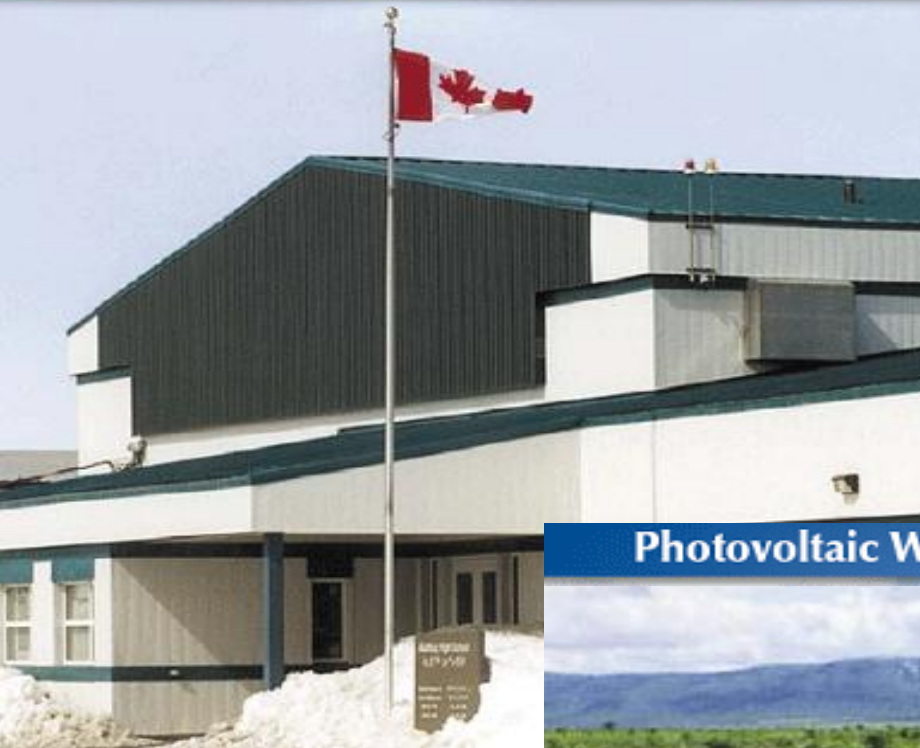
Points represent world's cities (~10,000). Red have in situ observations. Blue defer to NASA LaRC data sets (~5,000). Data for locations between points are found through a direct link to SSE.





# Projects Facilitated by RETScreen

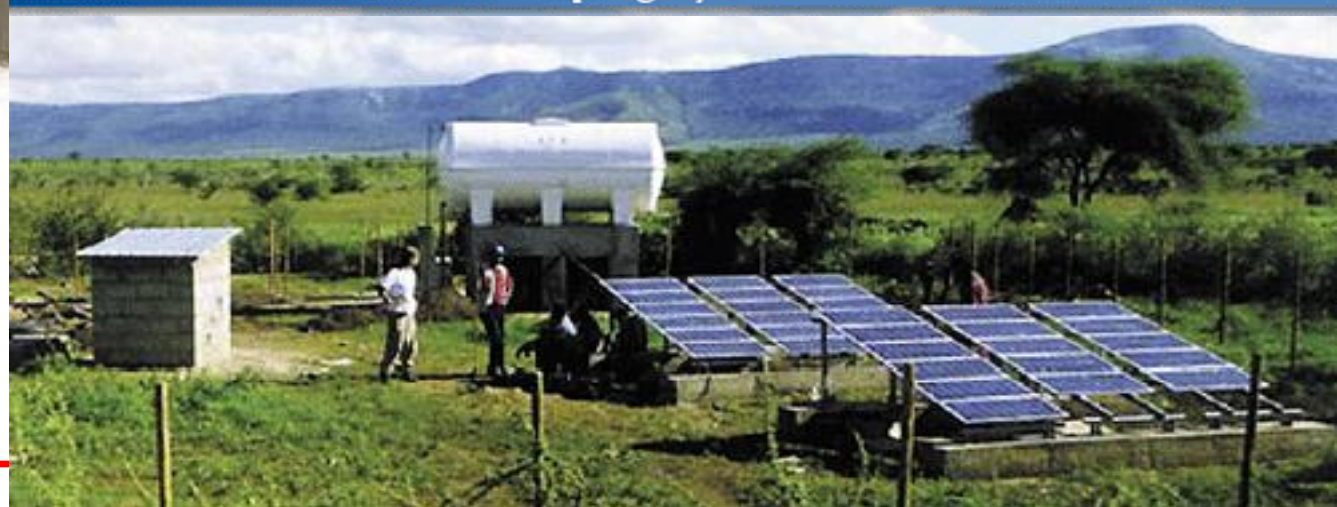
**RETSCREEN® INTERNATIONAL**  
**Solarwall® on High School in Northern Canada**



[www.retscreen.net](http://www.retscreen.net)  
**Solar Water Heating at Vancouver International Airport**



**Photovoltaic Water Pumping System in Africa**





## Five Step Sta



Settings &  
Site Conditions



Enter data in shaded cells  
from top to bottom  
of each worksheet

Integrated Featu

Climate  
Data



http://www.retscreen.net - RETScreen International

**RETScreen**

Country: China  
Province / State: Shanghai  
Climate data location: Shanghai

Latitude: °N 31.4  
Longitude: °E 121.5  
Elevation: m 4.0  
Heating design temperature: °C -0.4  
Cooling design temperature: °C 33.2  
Earth temperature amplitude: °C 14.7

Source: Ground, Ground, Ground, NASA, Ground, Ground

	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°F / °C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
Jan	43.2	73.0%	2.61	102.5	3.1	5.4	406	0
Feb	45.2	70.4%	3.08	102.4	3.0	6.4	330	0
Mar	49.1	75.1%	3.54	102.0	3.3	9.5	264	0
Apr	59.0	73.9%	4.46	101.5	3.2	14.3	90	150
May	68.9	74.6%	5.05	101.0	3.2	18.9	0	326
Jun	74.8	81.5%	4.64	100.6	3.2	22.8	0	414
Jul	82.6	80.0%	5.15	100.4	3.3	26.6	0	561
Aug	81.9	81.3%	4.82	100.5	3.5	26.6	0	549
Sep	75.9	76.6%	4.09	101.1	3.4	23.1	0	432
Oct	66.7	73.8%	3.47	101.8	2.9	18.4	0	288
Nov	56.3	73.0%	2.91	102.3	3.0	13.2	135	105
Dec	46.0	71.7%	2.56	102.6	2.9	7.7	316	0
Annual	62.2	75.4%	3.87	101.6	3.2	16.1	1,541	2,825
Source	Ground	Ground	NASA	NASA	Ground	NASA	Ground	Ground

Measured at: m 10 0

Sensitivity &  
Risk Analysis



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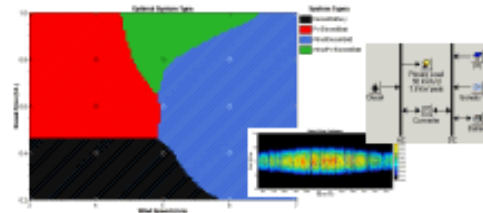
- Engineering Textbook
- Case Studies
- Marketplace & Maps

7/22/2010

© Minister of Natural Resources Canada 1997-2006.

NASA LaRC Research and Applied Science

RETScreen® International



## About HOMER

### Overview

User Interface  
Version History  
User Testimonials  
Ask Tom (FAQs)

### Downloads

Software (Visit  
HOMER Energy)  
Getting Started Guide  
(PDF File, 720 kB)  
Brochure (English)  
(PDF File, 964 kB)  
Brochure (Spanish)  
(PDF File, 1.3 MB)  
Bibliography  
(PDF File, 47 KB)  
Webcast Materials  
May 16, 2006

### Contact Us

Names and Addresses

Security & Privacy

## New Distribution Process for NREL's HOMER Model

**Note! HOMER is now distributed and supported by [HOMER Energy](http://www.homerenergy.com) ([www.homerenergy.com](http://www.homerenergy.com))**

To meet the renewable energy industry's system analysis and optimization needs, NREL started developing HOMER in 1993. Since then it has been downloaded free of charge by more than 30,000 individuals, corporations, NGOs, government agencies, and universities worldwide.

HOMER is a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and distributed generation (DG) applications. HOMER's optimization and sensitivity analysis algorithms allow the user to evaluate the economic and technical feasibility of a large number of technology options and to account for uncertainty in technology costs, energy resource availability, and other variables. HOMER models both conventional and renewable energy technologies:

#### Power sources:

- solar photovoltaic (PV)
- wind turbine
- run-of-river hydro power
- generator: diesel, gasoline, biogas, alternative
- electric u
- microtur
- fuel cell

#### Storage:

- battery bank
- hydrogen
- flow batteries
- flywheels

*"Best hourly assessment tool for hybrid renewable electric generation systems in the world - bar none."*

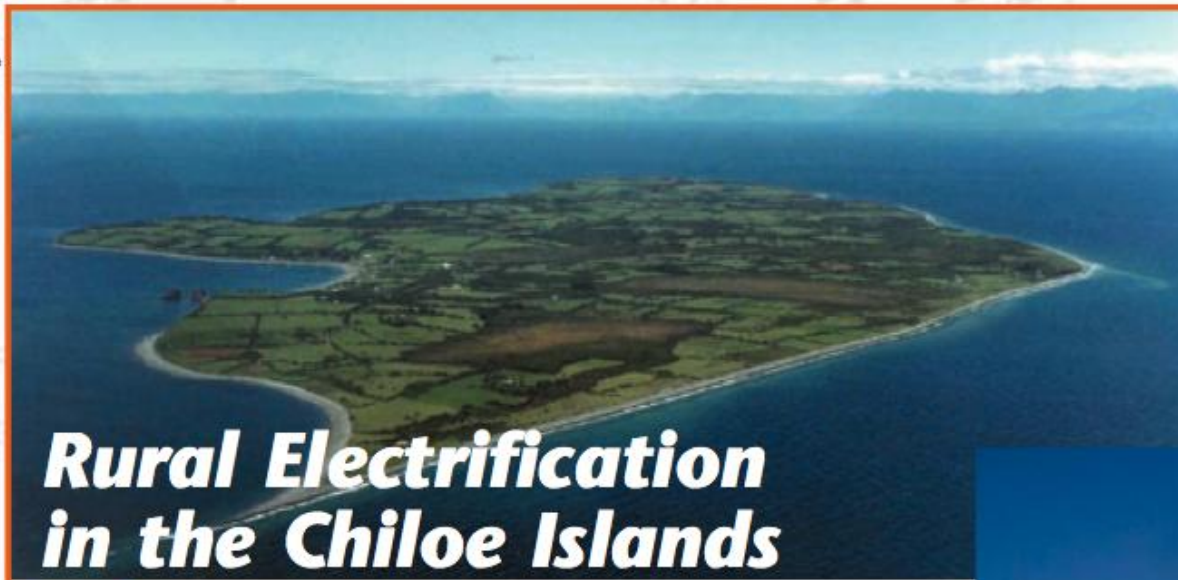
Dr. Jan F. Kreider

Building Systems Program, University of Colorado, January 2008





# HOMER Example Project



*The island of Tac, Region de los Lagos, Chile*

## Rural Electrification in the Chiloe Islands

**T**he Chiloe Islands are located off the Pacific Coast of Southern Chile. Of the more than 40 islands in the group, 32 are too far from the coast to be connected to the mainland electric grid and either have no access to electricity, or intermittent access provided by diesel generators. The islands range in size from 12 to 450 homes, with projected loads ranging from 17 to 1004 kWh/day. Economic activity on the islands includes farming, animal husbandry, and fishing. NREL, through a cooperative agreement between the governments of Chile and the United States, worked with a team of local and international experts to implement a pilot hybrid power system on Isla Tac, one of the Chiloe islands. The team conducted economic, loads, and renewable resource studies and used the results from those studies as inputs to HOMER.

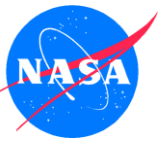
An optimization analysis using HOMER showed that a wind-diesel system with battery storage would most cost-effectively supply the energy required by the island. HOMER's sensitivity analysis capability helped the team assess the impact of fuel price on the least-cost system design.



Ian Baring-Gould

*The Isla Tac Power system provides power to the islands' 82 families.*

The team also used two other NREL models: ViPQR to determine electric distribution mini-grid costs, and Hybrid2 to finalize the design of the hybrid power system. This work helped lead to a \$40 million multilateral development bank loan to provide rural electrification projects, including replication of this pilot project, across the entire Chiloe island region.



# SWERA 2: Renewable Resources for Developing Nations

- USGS-led ROSES Proposal

- Data archive, user interface at UNEP GRiD facility

- *NASA role:* supply global data parameters



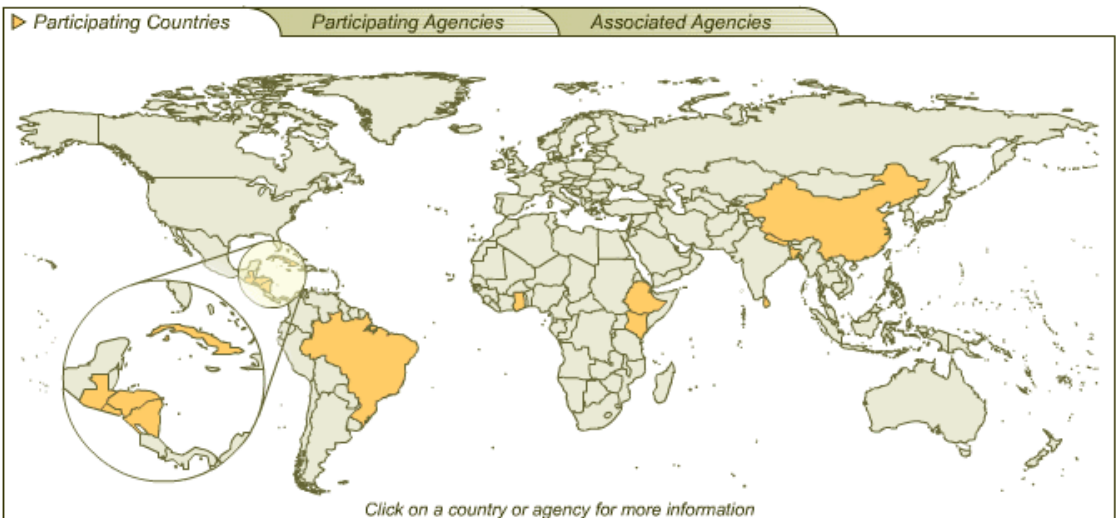
## Solar and Wind Energy Resource Assessment



### Welcome To SWERA

The **SWERA** website provides information about solar and wind energy resources in thirteen partner countries around the world. Products held in the SWERA archive include data on wind and solar energy potential, plus detailed country energy analyses. To learn more about renewable energy in each country or the partner agencies, click on the map or the menu. SWERA is a UNEP (United Nations Environment Programme) project with co-financing from GEF. The goal is to provide solar and wind energy assessments to potential investors and the public to promote more effective use of alternative energy resources.

Now with the completion of the successful pilot project, SWERA is being expanded into a full Programme offering resource information and mapping tools across the spectrum of renewable energy sources. All information and tools can be found in one on-line location with a common user interface... click [here](#) for more details.



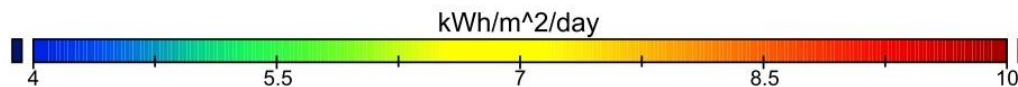
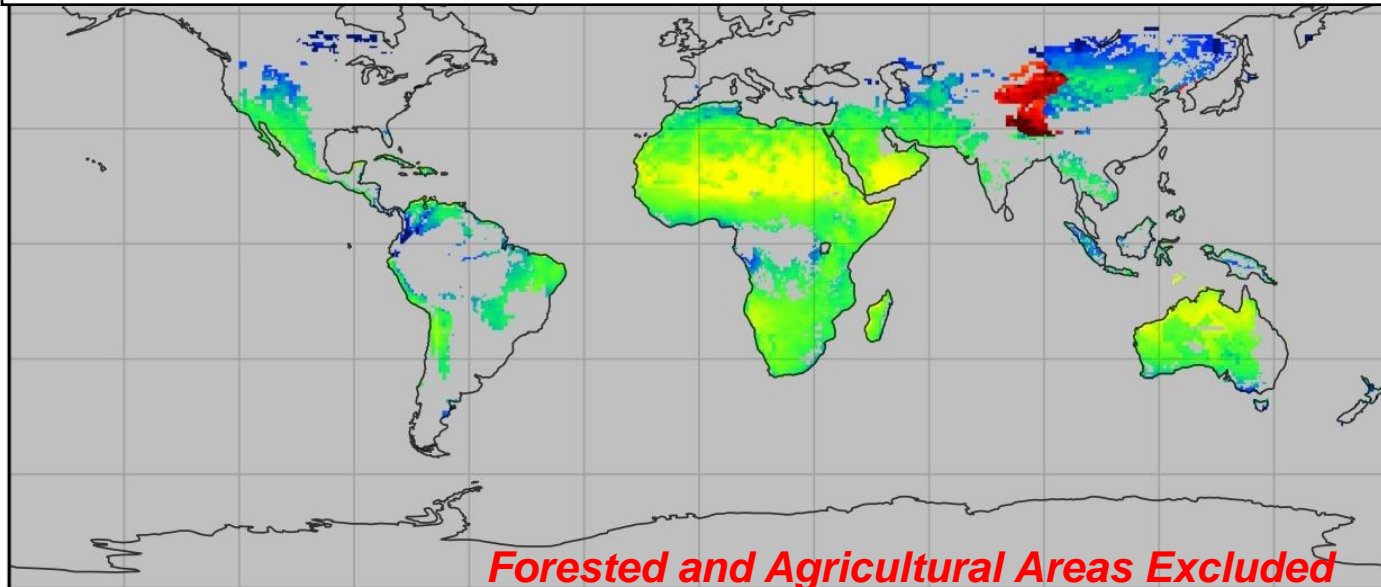


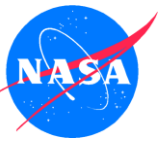


# PNNL Integrated Assessment Model Initialization with NASA Data

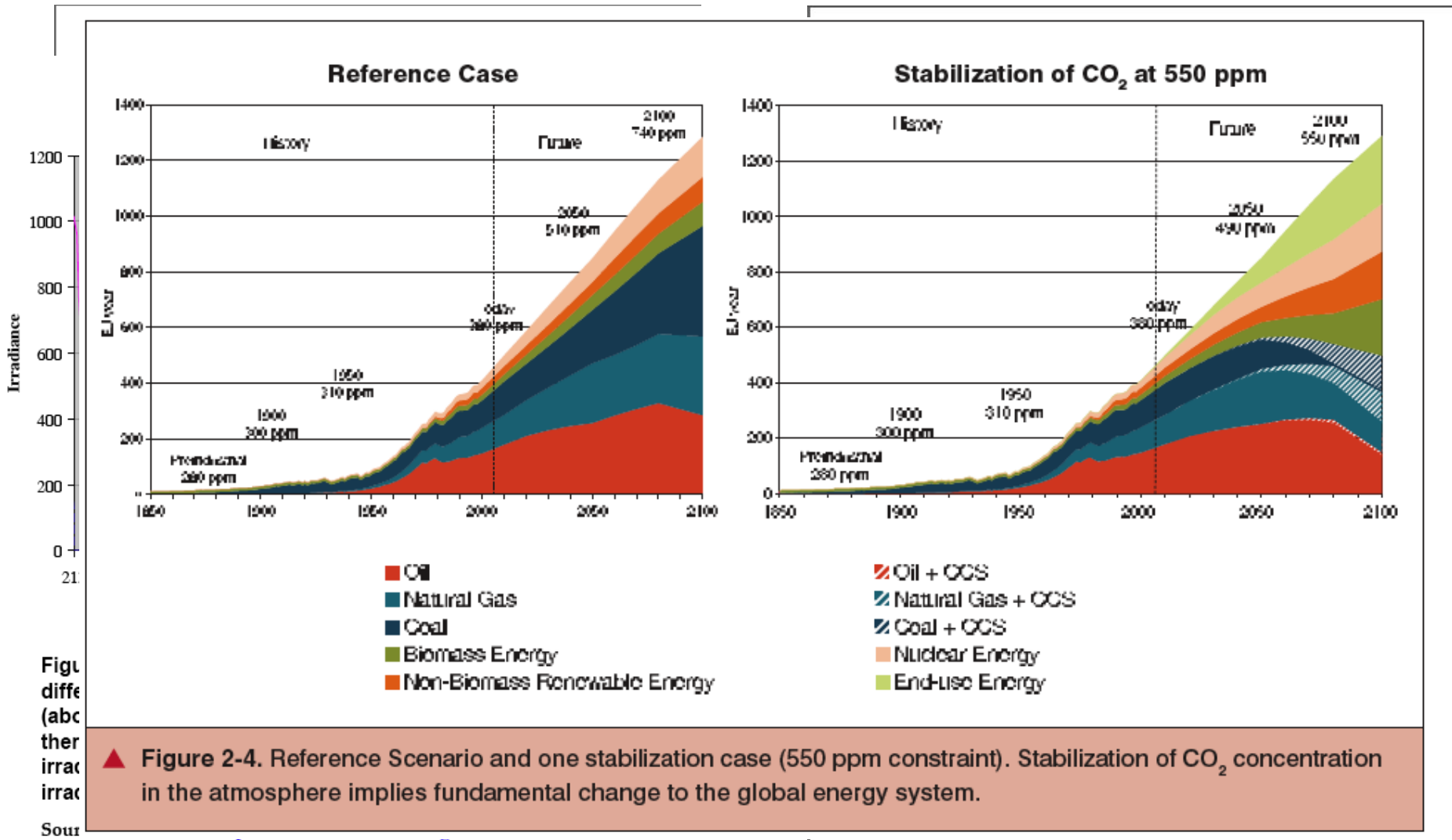
*PNNL/Joint Global Change Research Center uses NASA  
POWER data sets for initiation of MiniCAM 50-year energy  
market forecasts for policy planning*

Direct Solar Irradiance for areas  
with 50 or less no-sun days per year





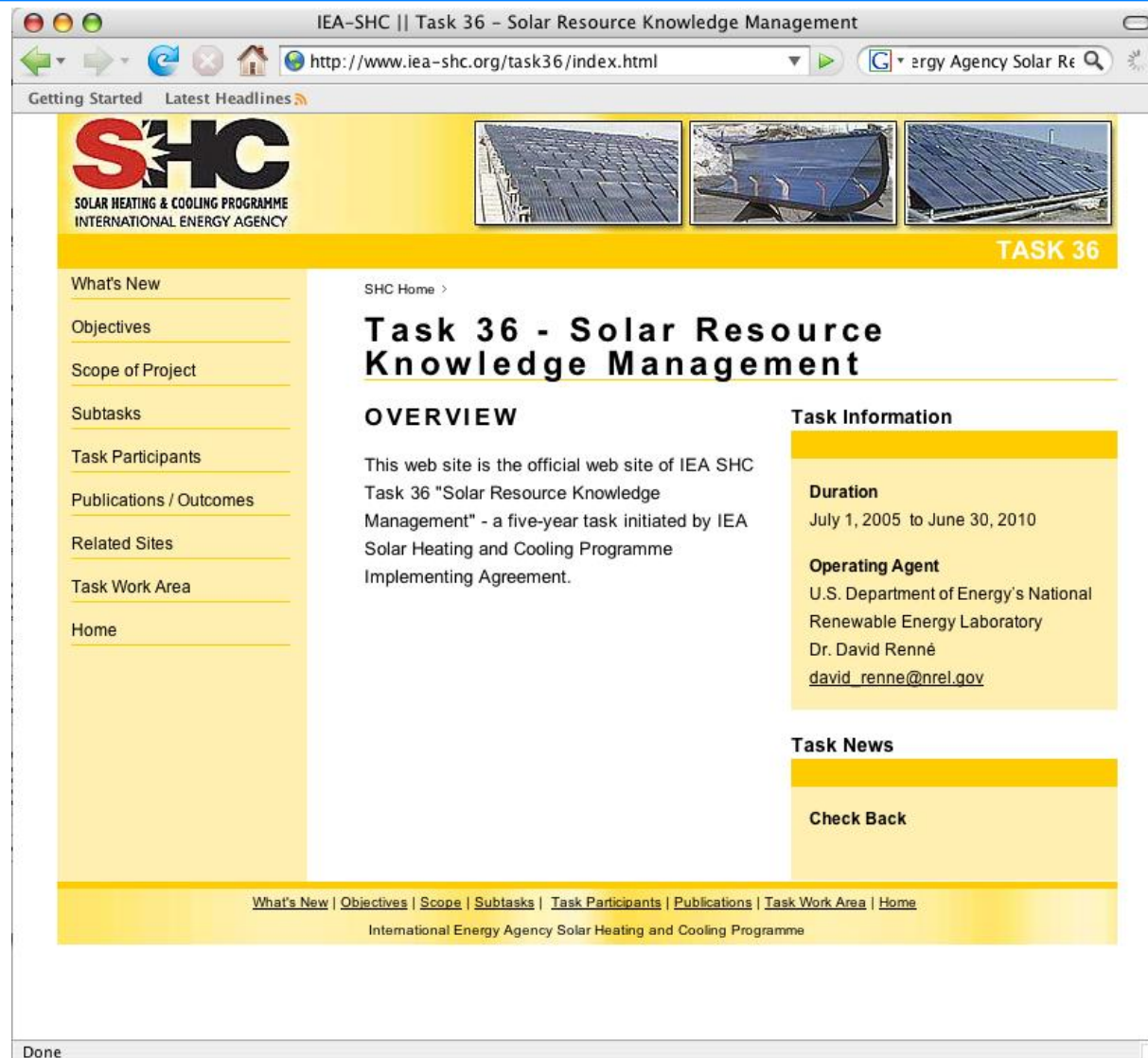
# PNNL's Assessment Results



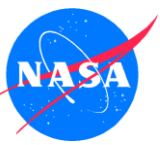


# NASA POWER Contributes to International Energy Agency Task

- *International collaboration representing >8 nations; >15 Organizations*
- *5 Year Task*
- *DOE/NREL led*
- *NASA/POWER contributing expertise on solar resource estimation and validation, user and interface information, data sets and research*
- *Result: More accessible and reliable information for solar energy projects*

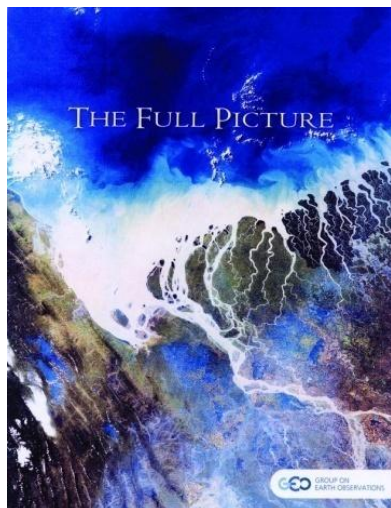


The screenshot shows a web browser window displaying the IEA-SHC Task 36 website. The browser's address bar shows the URL <http://www.iea-shc.org/task36/index.html>. The website has a yellow header with the SHC logo (SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY) and three images of solar panels. A navigation menu on the left lists: What's New, Objectives, Scope of Project, Subtasks, Task Participants, Publications / Outcomes, Related Sites, Task Work Area, and Home. The main content area is titled "Task 36 - Solar Resource Knowledge Management" and includes an "OVERVIEW" section stating: "This web site is the official web site of IEA SHC Task 36 'Solar Resource Knowledge Management' - a five-year task initiated by IEA Solar Heating and Cooling Programme Implementing Agreement." To the right, a "Task Information" box lists the "Duration" as "July 1, 2005 to June 30, 2010" and the "Operating Agent" as "U.S. Department of Energy's National Renewable Energy Laboratory Dr. David Renné" with the email [david\\_renne@nrel.gov](mailto:david_renne@nrel.gov). Below this is a "Task News" section with a "Check Back" link. A footer at the bottom contains a list of links: [What's New](#), [Objectives](#), [Scope](#), [Subtasks](#), [Task Participants](#), [Publications](#), [Task Work Area](#), and [Home](#), followed by the text "International Energy Agency Solar Heating and Cooling Programme".



# NASA Energy Program Contributions to GEO and CEOS

- **Core member of GEO energy community of practice**
  - Applied Sciences-funded activities contribute directly to GEO work plan tasks EN06-04, EN07-01, EN07-03
  - IEA activity, leveraged with ESA partnership, provided first **GEO energy early achievement project**, “Solar Information for Developing Countries”
  - One of principal authors of **GEO Energy Strategic Plan**, which closely mirrors Applied Sciences Program plan
  - **Lead for CEOS Energy SBA** activities (GEO-CEOS remapping activities)
  - Energy articles published in **GEO summit publication** (two with NASA involvement)



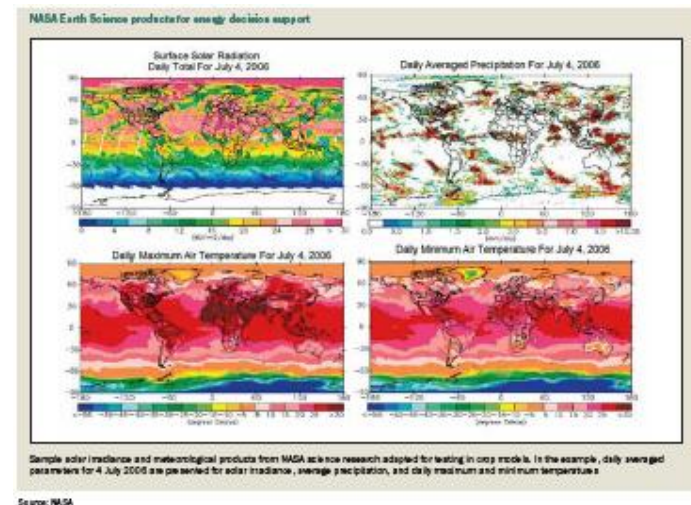
## Informing decision making in the energy sector using NASA spaceborne observations and model predictions

Richard S. Eckman and Paul W. Stackhouse, Jr, NASA Langley Research Center

Adapting global sets of spaceborne observations — often made for diverse research purposes — to enhance end-user decision making remains a challenge for the Global Earth Observation System of Systems (GEOSS). The US National Aeronautics and Space Administration (NASA) Applied Sciences Program (the Program) seeks to identify innovative uses for NASA-derived spaceborne observations and model predictions and connect with end users to enhance their ability to make management and policy decisions. The Applied Sciences Program's Energy Management application extends NASA Earth science research results to improve decisions and assessments for energy production and energy efficiency, by interacting with partners to benchmark NASA research datasets derived from the analysis of historic and current observations and models to meet energy sector needs. These partners are other government agencies (both domestic and international), academia, professional organizations and the

International Satellite Cloud Climatology Project (ISCCP), Surface Radiation Budget (SRB), Global Modeling and Assimilation Office (GMAO), Goddard Earth Observing System (GEOS) meteorological analysis model, and Langley Research Center FLASHflux project providing near-real time surface radiative flux.

RETScreen ([www.retscreen.net](http://www.retscreen.net)) is a clean energy decision support system, developed by NRC's CANMET Energy Technology Centre, which enables end users to better assess the feasibility of renewable energy and energy efficiency projects, their costs, and greenhouse gas mitigation benefits. Surface solar energy measurements available from ground observations are often sparse or unavailable in the developing world. NASA's satellite-derived global observations and

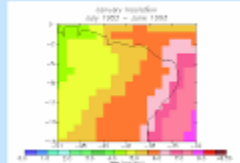
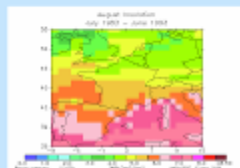




## SSE Data Set



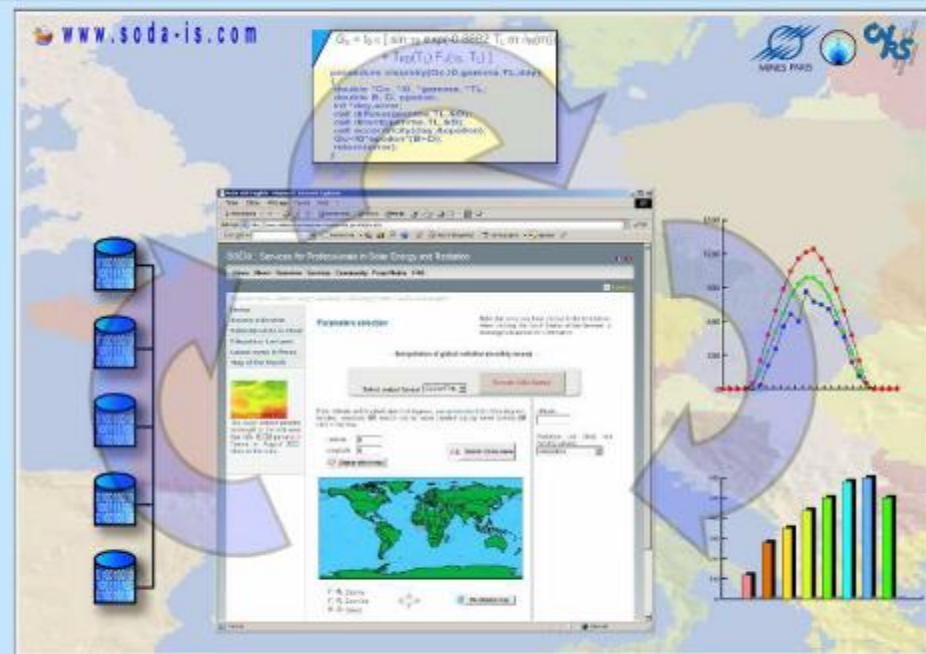
Access through:  
<http://eosweb.larc.nasa.gov/sse/>



- Monthly averaged from 11 years of data (1983-1993)
- Data tables for a particular location
- Color plots on both global and regional scales
- Over 200 satellite-derived meteorology and solar energy parameters
- Data for the RETScreen® Clean Energy Project Analysis Software

## GEOSS: First Energy Demonstration

### The SoDa Service Integrator

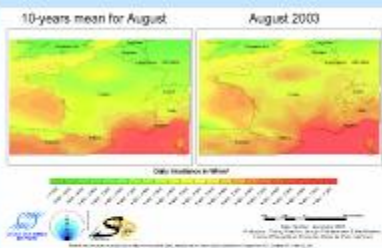


Hosted by École des Mines de Paris

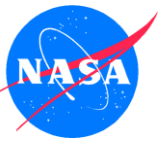
## Helioclim Database



Access through SoDa:  
<http://www.soda-is.com/>

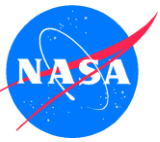


- Database and time-series of irradiance or irradiation
- Produced by the processing of satellite images, especially from the Meteosat series of satellites
- Covering Europe, Africa, the Mediterranean Basin, the Atlantic Ocean and part of the Indian Ocean
- Period runs from 1985 onwards



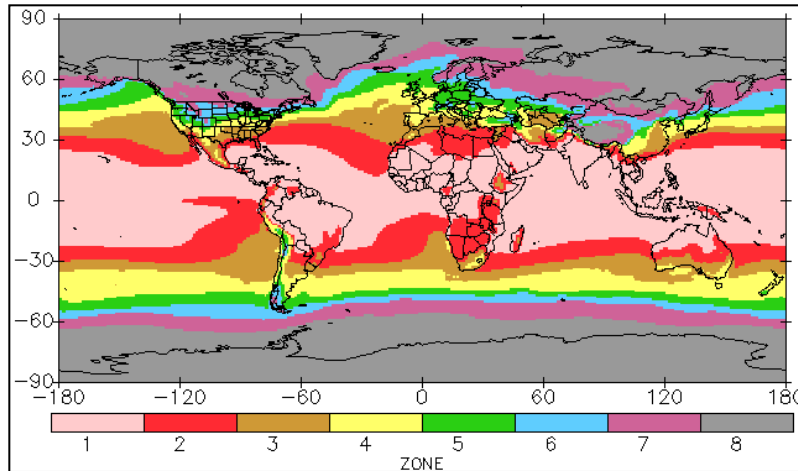
# Current and Potential Energy Applications

- ***Building data sets for design (DOE, ASHRAE)***
  - ESSM: GMAO GEOS-4, MERRA, GOCART
  - Satellite-based: GEWEX SRB
- ***Advanced Long-term Solar Mapping (NREL)***
  - Earth System Science models (ESSM): GMAO MERRA, GOCART
  - Satellite-based: ISCCP B1U (w/ 8km pixels), TOVS-TOMS
- ***Building Targeting and Monitoring (NASA, NRCan)***
  - ESSM: GMAO operational assimilation
  - Satellite-based: FLASHFlux
- ***Load Forecasting (Battelle, Ventyx)***
  - ESSM: GMAO operational assimilation, forecasts; SPORT
  - Satellite-based: FLASHFlux
- ***Solar Energy Forecasting (NREL, SUNY)***
  - ESSM: GMAO forecasts
  - Satellite-based: FLASHFlux (for validation)

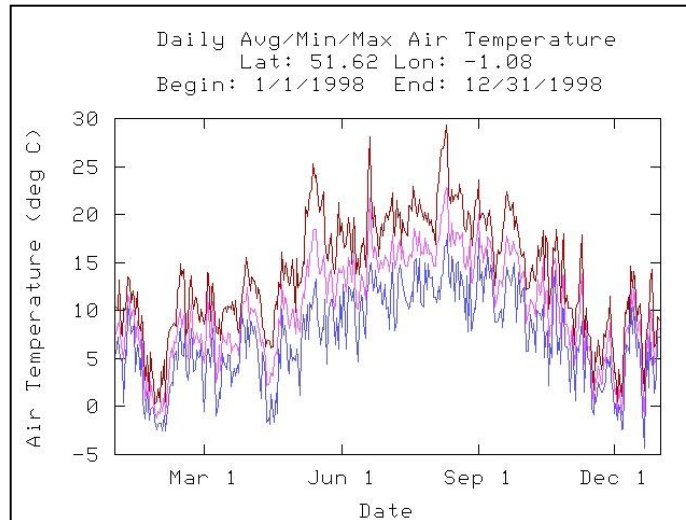


# Long-term Climate Information For Building Design

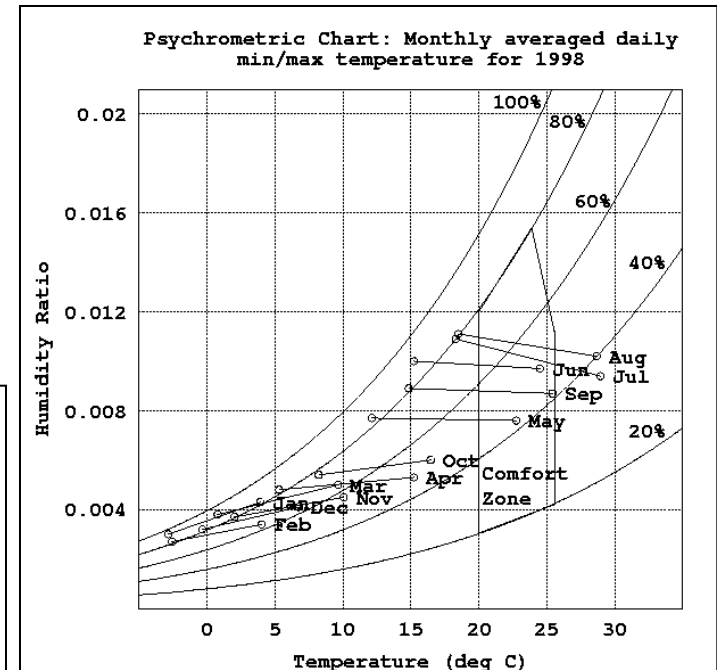
## Global Building Design Climate Zones (with ASHRAE and DOE)



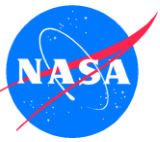
## Location Specific Daily/Monthly Averaged Climate Information



## Location Specific Traditional Architectural Comfort Zone Design Charts (with AIA)



**30 Years Needed!**



# Current and Potential Energy Applications

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# Advanced Long-term Solar Mapping

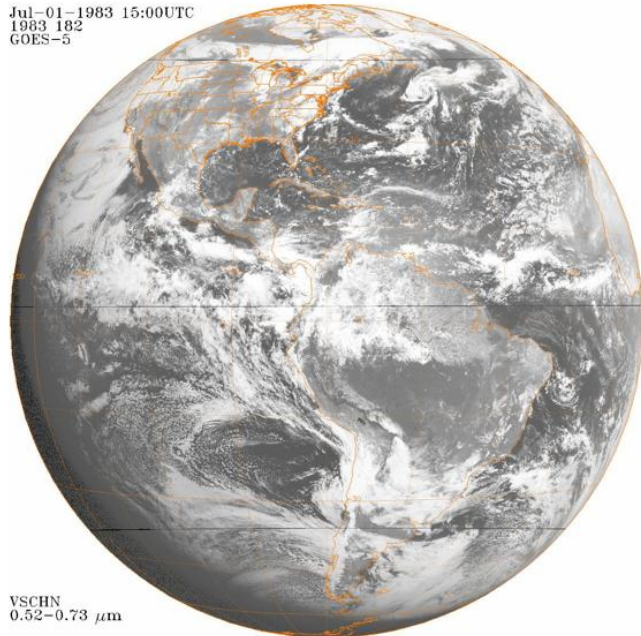
*Using newly archived ISCCP B1U and latest long-term H<sub>2</sub>O, O<sub>3</sub>, aerosol information develop long-term solar maps at high resolution*



[Satellite Data](#) > [GIBBS](#) > [1983](#) > [July 01](#)

July 01, 1983 15:00 UTC  
Channel: Visible (~0.65um)  
Satellite: GOES-5

Jul-01-1983 15:00UTC  
1983 182  
GOES-5



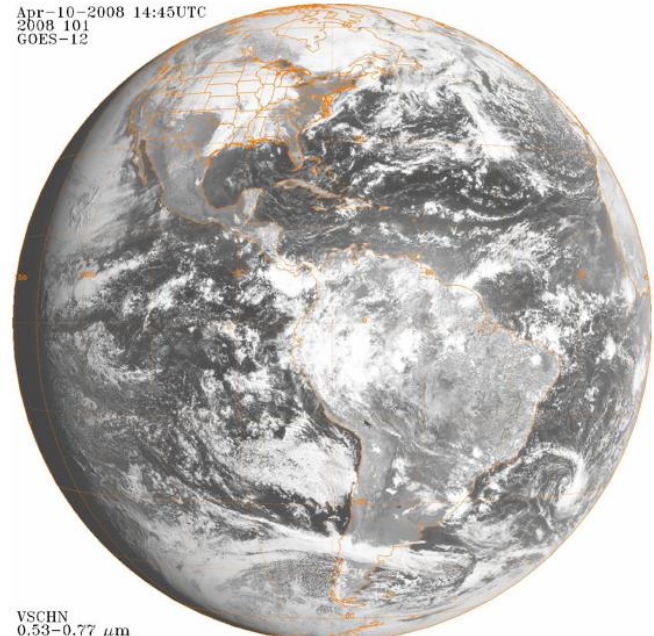
VSCHN  
0.52-0.73  $\mu\text{m}$



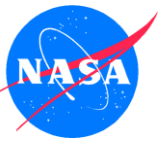
[Satellite Data](#) > [GIBBS](#) > [2008](#) > [April 10](#)

April 10, 2008 15:00 UTC  
Channel: Visible (~0.65um)  
Satellite: GOES-12

Apr-10-2008 14:45UTC  
2008 101  
GOES-12

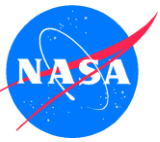


VSCHN  
0.53-0.77  $\mu\text{m}$



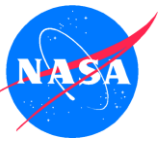
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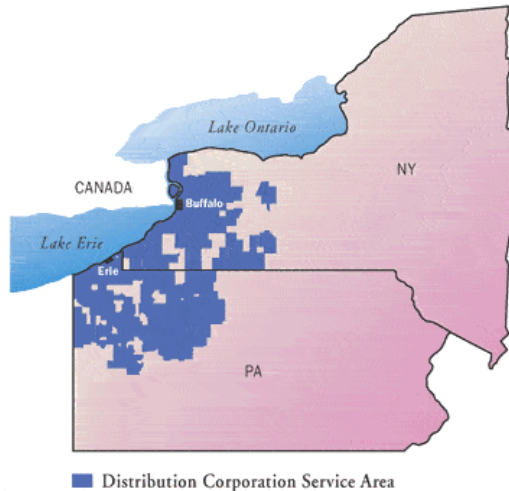
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  - ESSM: GMAO forecasts
  - Satellite-based: FLASHFlux (for validation)



# Energy Forecasting

*ROSES proposal w/ Battelle and NewEnergy to evaluation NASA long-term data sets (GMAO) and high resolution forecasts (SPORT)*



- Gas utilities use daily averaged data
- Daily averaged 4 years of POWER/FLASHFlux delivered for 4 regions
- Forecast errors reduced
- FLASHFlux data delivered weekly for the Ventyx Vector database

## Statistics Overview for Verification Period

Options

Group Name	Min MAPE	Max MAPE	Min MPE	Max MPE	Abs Min Err	Abs Max Err	Min % Err	Max % Err
New York Daily	4.07	6.48	-6.48	-1.26	14.15	19875.20	-23.41	5.77
Pennsylvania Daily	7.77	11.81	-146.12	-2.44	.00	.00	.00	.00

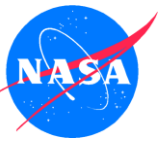
Profile Name	MAPE	MPE	Abs Min Err	Abs Max Err	Min % Err	Max % Err	Last Train Date
New York Standard NASA	4.07	-1.26	14.15	7712.64	-8.73	5.77	10/10/2008
New York Standard	6.48	-6.48	405.20	19875.20	-23.41	-.37	10/10/2008





# Conclusions

- *NASA Applied Science Program has and continues to yield significant results for nation and international programs through Science => Applications transfer*
- *Successes include supporting renewable energy and energy efficient technology optimization; thus are relevant to identified priorities in climate change mitigation and adaptation.*
- *The model of success in this field has been long-term partnerships featuring the development and dissemination of specifically tailored data sets.*
- *Data sets made available through web based interfaces provide opportunities for new projects and new partnerships*
  - Higher resolution and Hourly data needed!
  - Need for forecasted parameters growing



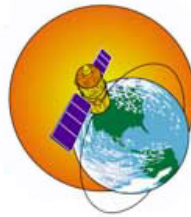
# POWER Web Site

<http://power.larc.nasa.gov>



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

[+ Visit NASA.gov](http://www.nasa.gov)



## Prediction Of World Energy Resource

Surface meteorology and Solar Energy (SSE-release 5) : A renewable energy resource web site sponsored by NASA's Science Mission Directorate, Earth-Sun System Division, Applied Sciences Program

Earth Science for Society: Accelerating the realization of economic and societal benefits from Earth science, information, and technology ...

[Home](#) [SSE - Renewable Energy Parameters](#) [Sustainable Buildings Parameters](#) [Agroclimatology Parameters](#)

### Access Data

- [Data Format](#)
- [SSE - Renewable Energy](#)
- [Sustainable Buildings](#)
- [Agroclimatology](#)

### Documentation

- [About the POWER Project](#)
- [About SSE - Renewable Energy](#)
- [About Sustainable Buildings](#)
- [About Biomass Fuel- Agroclimatology](#)
- [Global Geometry/Resolution](#)
- [Parameter Accuracy/Validation](#)
- [Methodology of Satellite Inferred Parameters](#)
- [Power Publications](#)

### Related Links

- [Science Mission Directorate](#)
- [NASA's Applications Program](#)
- [Atmospheric Science Data Center](#)
- [Other Related Sites](#)

### Navigation and Help

- [Partners](#)
- [POWER Archive Statistics](#)
- [Release Notes](#)
- [Acknowledgments Please](#)
- [Join POWER Mailing List/ Submit Questions](#)
- [FAQs](#)

### Processing, archiving, and distributing solar insolation and meteorological parameters

- **[SSE - RENEWABLE ENERGY:](#)** Satellite-derived data supporting Renewable Energy Technologies (RET's).
  - Over 200 primary and derived meteorology and solar energy parameters
  - Monthly averaged parameters from July 1, 1983 through June 30, 1993
  - Global coverage on a 1° latitude by 1° longitude grid
  - Color plots on both global and regional scales
  - Solar energy data for 1195 ground sites
  - Data for the [RETScreen](#)® Renewable Energy Project Analysis Software
- **[SUSTAINABLE BUILDINGS:](#)** Satellite-derived data for the preliminary design of buildings and associated renewable-energy power systems.
  - Global coverage on a 1° latitude by 1° longitude grid
  - Twenty Two year monthly averaged temperatures, wind and solar radiation from July 1, 1983 through June 30, 2005
  - Daily averaged solar radiation from July 1983 through June 2005
  - Daily humidity and air temperatures for 1983 and December 2006
  - Temperature and relative humidity on 3-hourly time steps
  - Psychrometer chart and Global and/or regional plots
- **[AGROCLIMATOLOGY:](#)** Satellite-derived solar and meteorological data supporting agro-technology
  - Global coverage on a 1° latitude by 1° longitude grid
  - Daily total solar radiation from July 1983 through June 2005; and July, 2006 through current with one month delay
  - Daily averaged dew point and air temperatures from January 1983 through December 2006;
  - Daily averaged precipitation from January 1997 - current with two month delay



[+NASA Privacy Statement, Disclaimer](#)  
[+ Freedom of Information Act](#)



Responsible Official:  
**Paul W. Stackhouse, Jr., Ph.D.**  
(e-mail: [paul.w.stackhouse@nasa.gov](mailto:paul.w.stackhouse@nasa.gov))  
Last Updated: Wed May 09 2007 09:42:21  
GMT-0400 (EDT)



# Using HOMER: System Selection

1. User first selects from list of hybrid options under consideration from main page

The screenshot shows the HOMER software interface for a project titled "Residential grid-connected PVbakersfield simple.hmr". The interface includes a menu bar (File, View, Inputs, Outputs, Window, Help) and a toolbar. The main workspace is divided into several sections:

- Equipment to consider:** A diagram showing a "Grid" connected to an "AC" bus, which then branches into "Electrical" (14 kW, 3.7 kW) and "Conversion" (Conve) components.
- Loads:** A list of load types with checkboxes: Primary Load 1, Primary Load 2, Deferrable Load, Thermal Load, and Hydrogen load. A red arrow points to this section.
- Resources:** A section for "Solar resource".
- Grid:** A section with radio buttons for "Do not model grid", "System is connected to grid", and "Compare stand-alone system to grid extension".
- Components:** A list of components with checkboxes: PV, Wind Turbine 1, Wind Turbine 2, Hydro, Generator 1, Generator 2, Generator 3, Battery, Converter, Electrolyzer, Hydrogen Tank, Reformer, and Hybrid Electric Vehicle.

The bottom of the interface includes a "Document" section with fields for "Author" (Peter Lilienthal) and "Notes".



# Using HOMER: Obtain Solar Resource from NASA

2. User then specifies information about PV System

3. Then specifies solar resource for the given location

4. User can select to go to NASA's web site for data

**PV (Photovoltaic) Inputs**

**Solar Resource Inputs**

File Edit Help

HOMER uses the solar resource inputs to calculate the PV array power for each hour of the year. Enter the latitude, and either an average daily radiation value or an average clearness index for each month. HOMER uses the latitude value to calculate the average daily radiation from the clearness index and vice-versa.

Hold the pointer over an element or click Help for more information.

Location

Latitude   ☒ North ☐ South Time zone (GMT-08:00) Pacific Time (US & Canada)

Longitude   ☐ East ☒ West

Data source: ☒ Enter monthly averages ☐ Import hourly data file **Get Data Via Internet**

Baseline data

Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.472	2.370
February	0.546	3.470
March	0.566	4.630
April	0.611	6.070
May	0.645	7.160
June	0.678	7.830
July	0.685	7.730
August	0.683	7.060
September	0.670	5.870
October	0.642	4.420
November	0.567	3.010
December	0.475	2.190
Average:	0.623	5.159

**Solar Resource**

Daily Radiation (kWh/m2/d) Clearness Index

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

— Daily Radiation — Clearness Index

Scaled data for simulation

Scaled annual average (kWh/m2/d)

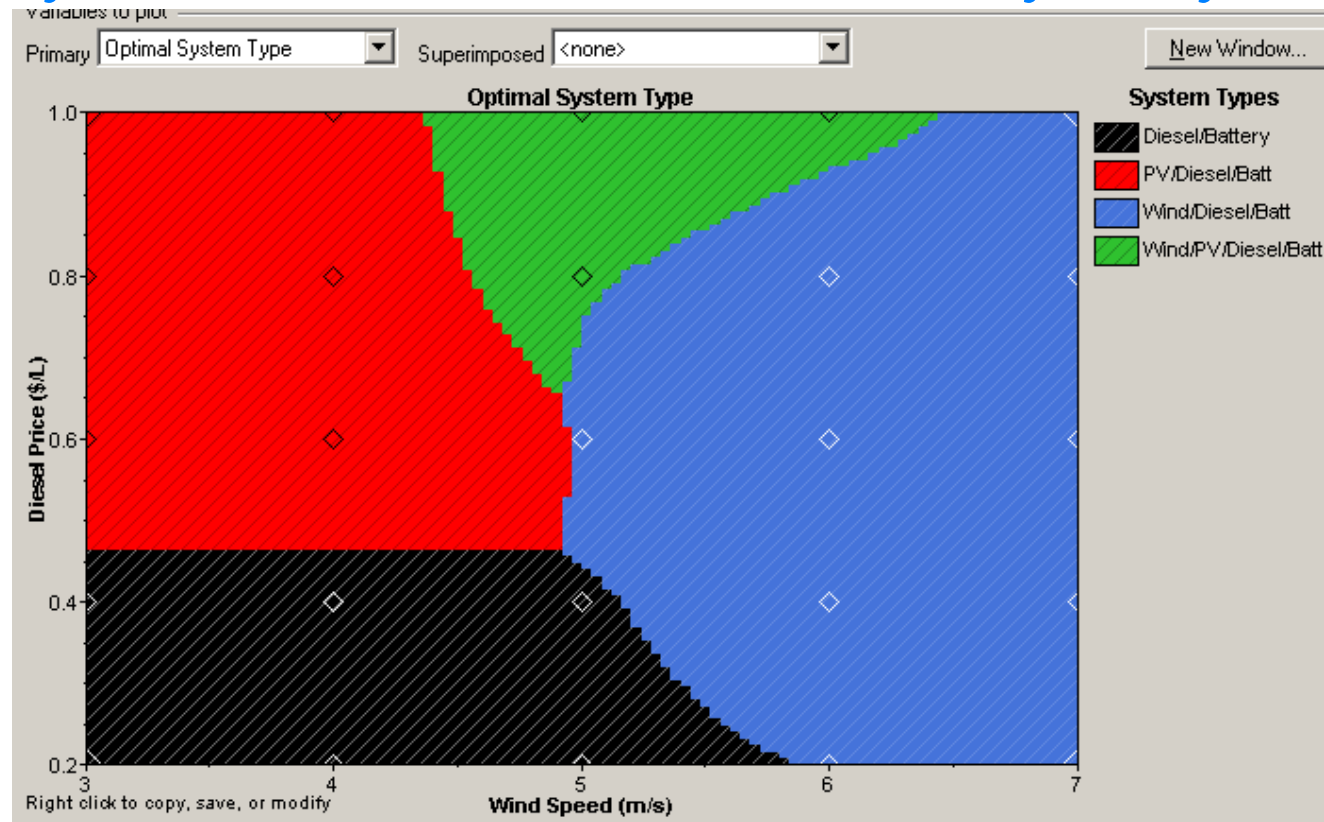
Plot... Export... Help Cancel OK



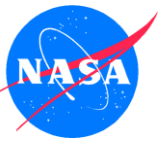


# HOMER Results and Impact

## 5. User analyzes the economic return for various hybrid systems



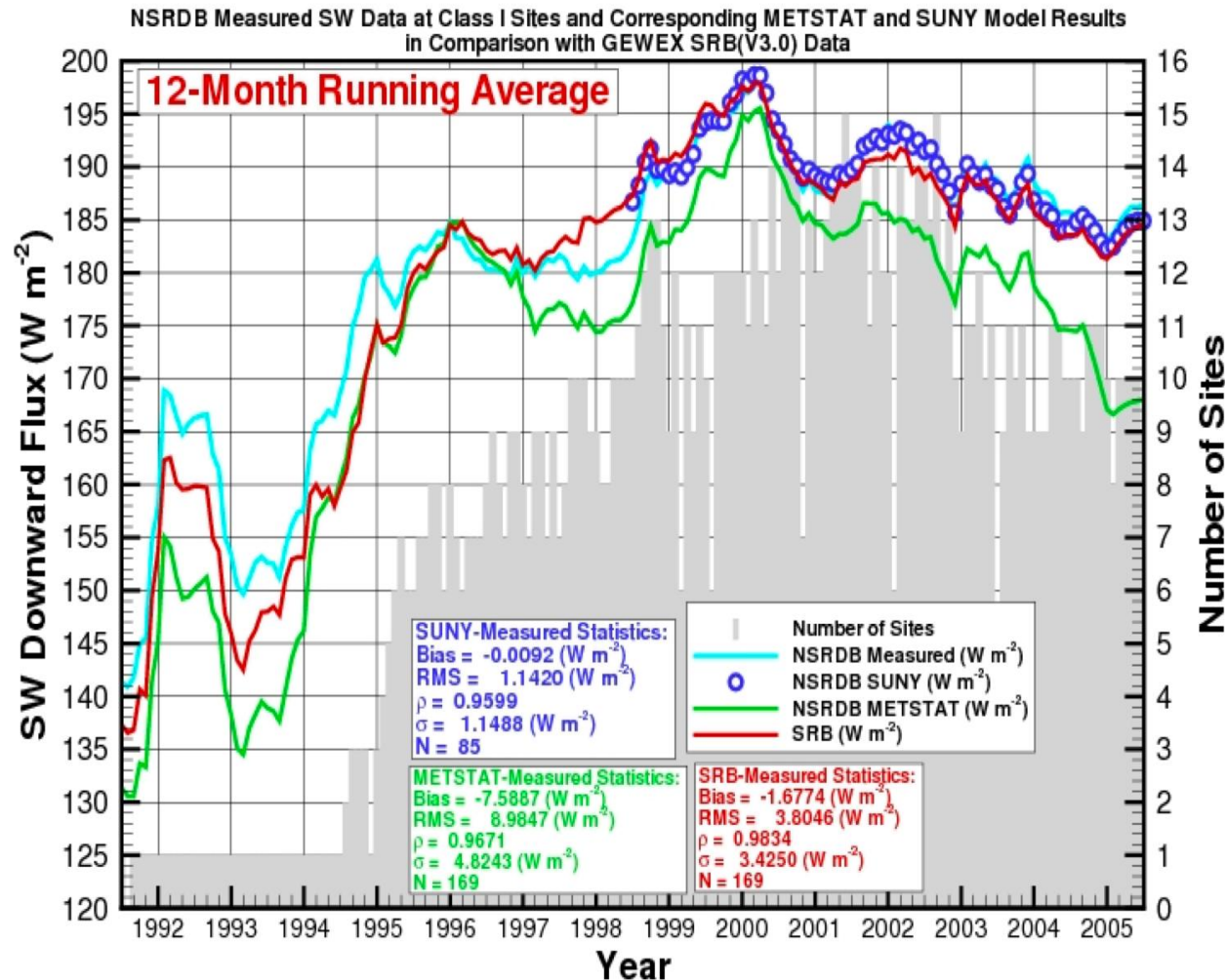
- **NASA's data allows quick and easy access to required information for any location around the globe**
- **Most users now use the data available via NASA's internet protocol**

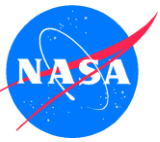


# Long-term Solar Mapping

## Advantages: NSRDB

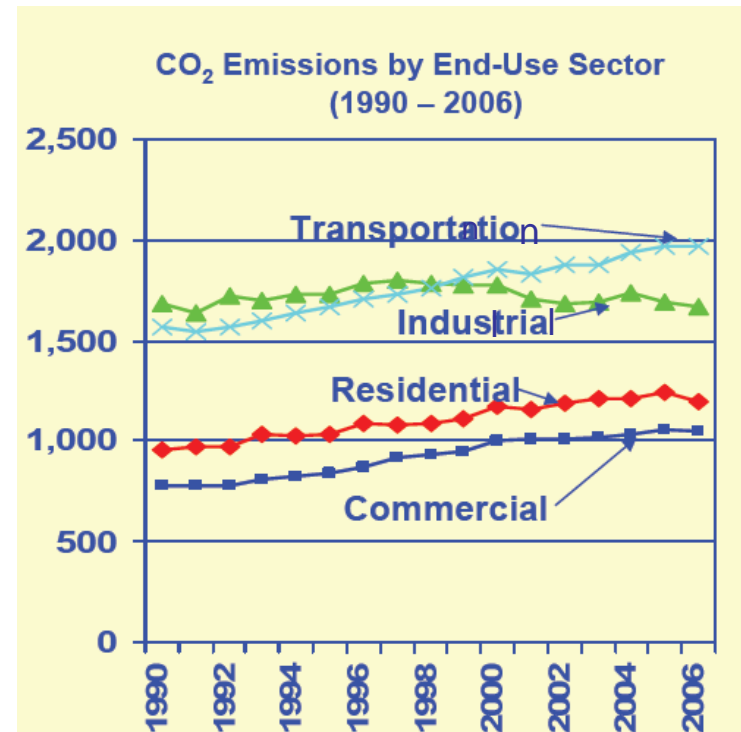
- NSRDB Class I Site Ensemble shows significant Year-to-year variability ( $\pm 10 \text{ W m}^{-2}$ )
- GEWEX SRB/SUNY ensemble at same locations largely captures variability
- Ensemble ground-based inference methods give higher uncertainties





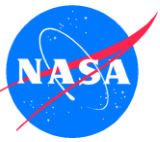
# Energy & Climate Change Challenge

- According to the US EIA commercial and Residual Buildings account for:
  - **39% of all energy usage**
  - **36% of all GHG emissions**
- IPCC: 90% probability that climate change is due to anthropogenic GHG emissions.
- US and International political, scientific and applied research priorities are aiming at strategies for mitigation and adaptation to potential global change.
- Energy efficiency/renewable energies growing 30-50% per year; represent one solution to face issues.



Source: Energy Information Administration

**Challenge: Apply NASA scientific expertise, models, and satellite-derived and in-situ measurements to develop applied science data sets for industry, academia, and policy makers in the arena of energy and climate change.**



# RETScreen Impact



RETScreen® INTERNATIONAL

www.retscreen.net

- *Clean energy technologies have matured, many cost-effective applications exist and markets are growing rapidly*
- *Initial planning stage is where clean energy technologies must be properly considered by planners, decision-makers and industry*
- *RETScreen® simplifies preliminary evaluations*
  - Requires relatively small amounts of input data
  - Calculates key technical & financial viability indicators automatically
  - Costs 1/10th the amount of other assessment methods:
    - NASA data improves applicability to globe
  - Standardized procedures allow objective comparisons
  - Increases potential for successful clean energy project implementation

